Physiological basis of ECG

INTRODUCTION

- **Electrocardiography** is the technique by which electrical activities of the heart are studied
- Einthoven Willem, considered the father of electrocardiogram (ECG).
- **Electrocardiograph** is the instrument (machine) by which electrical activities of the heart are recorded
- **Electrocardiogram** graphical registration of electrical activities of the heart

USES OF ECG

- **determining and diagnosing**

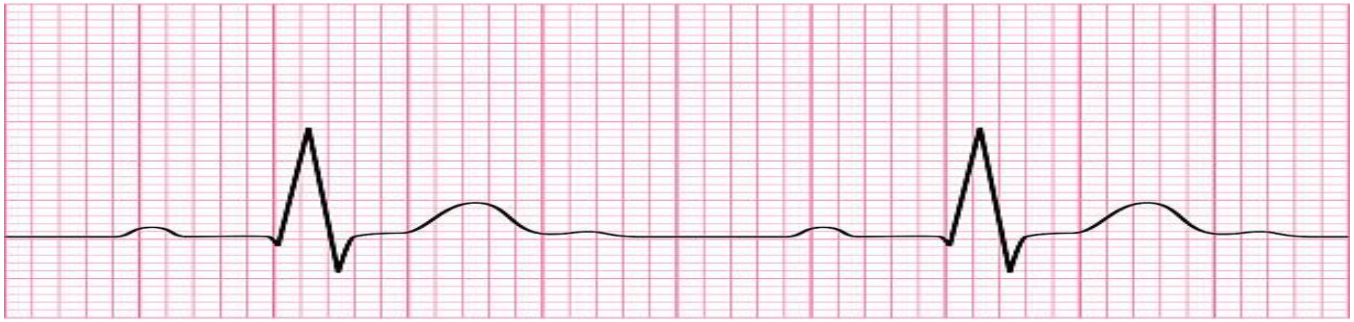
1. Heart rate
2. Heart rhythm
3. Abnormal electrical conduction
4. Poor blood flow to heart muscle (ischemia)
5. Heart attack

ECG principle

- It works on the principle that a contracting muscle generates a small electric current that can be detected and measured through electrodes suitably placed on the body

ELECTROCARDIOGRAPHIC GRID

- refers to the markings (lines) on ECG paper
- ECG paper has horizontal and vertical lines at regular intervals of 1 mm.
- Every 5th line (5 mm) is thickened



- **DURATION**

On X-axis

1 mm = 0.04 second

5 mm = 0.20 second

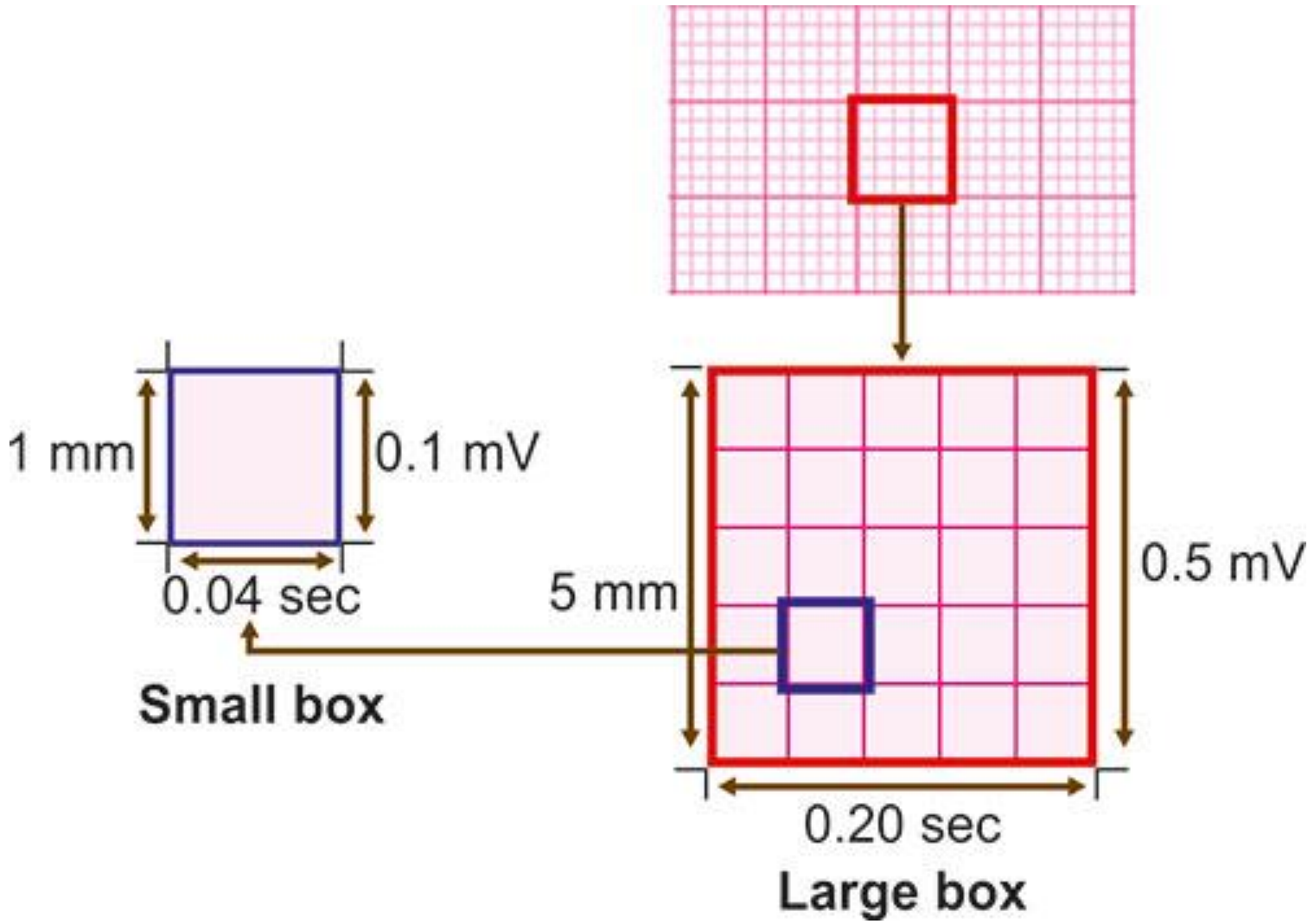
- **AMPLITUDE**

On Y-axis

1 mm = 0.1 mV

5 mm = 0.5 mV

SPEED OF THE PAPER- 25 mm/second


1 mm
0.1 mV
0.04 sec
Small box
5 mm
0.5 mV
0.20 sec
Large box

ECG LEADS

- ECG is recorded by placing series of electrodes on the surface of the body.
- These electrodes are called ECG leads and are connected to the ECG machine

- ECG is recorded in 12 leads, which are generally classified into two categories.

I. Bipolar leads

II. Unipolar leads

BIPOLAR LIMB LEADS

- Two limbs are connected to obtain these leads and both the electrodes are active recording electrodes, i.e. one electrode is positive and the other one is negative
- Standard limb leads are of three types:

a. Limb lead I

b. Limb lead II

c. Limb lead III

➢ Lead I

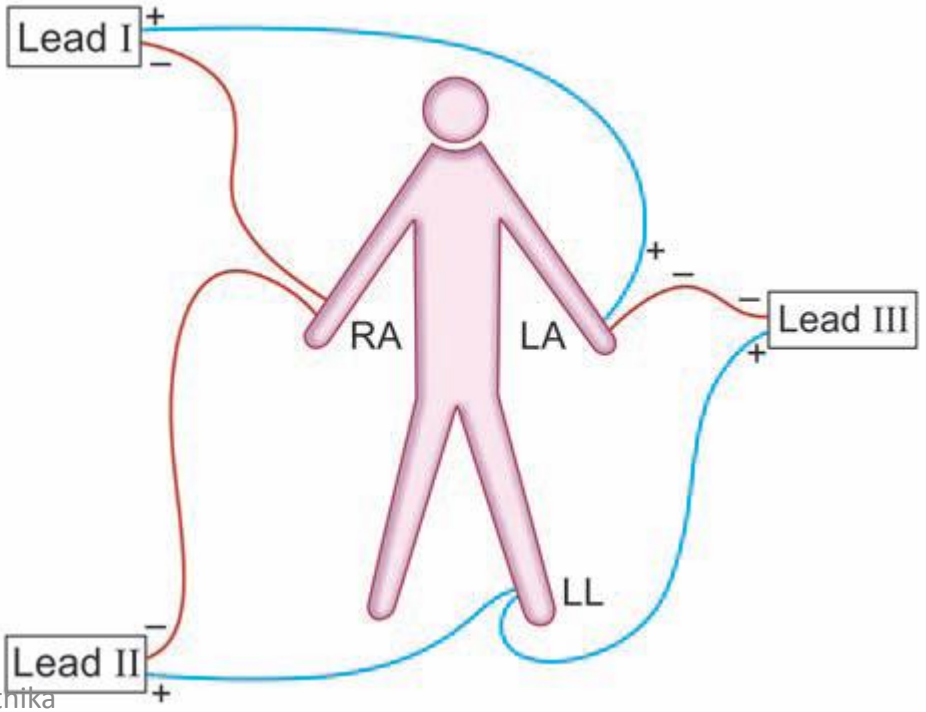
- obtained by connecting right arm and left arm.
- Right arm is connected to the negative terminal of the instrument and the left arm is connected to the positive terminal.

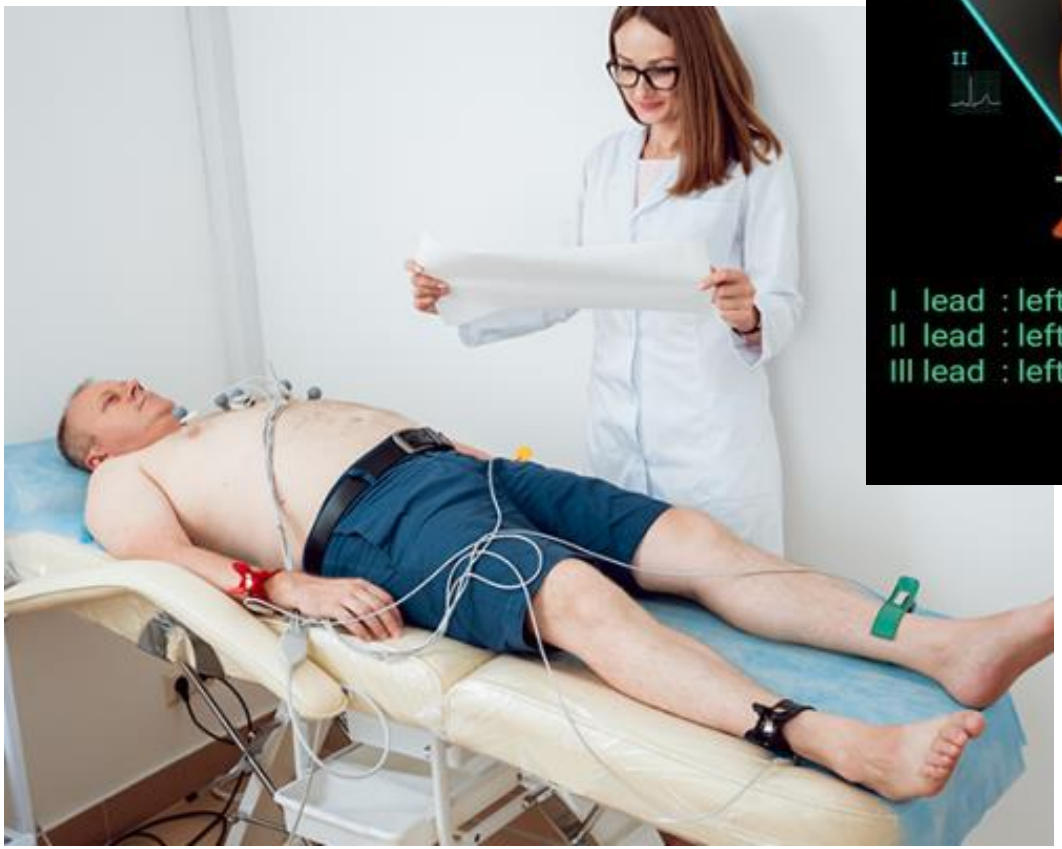
➢ Lead II

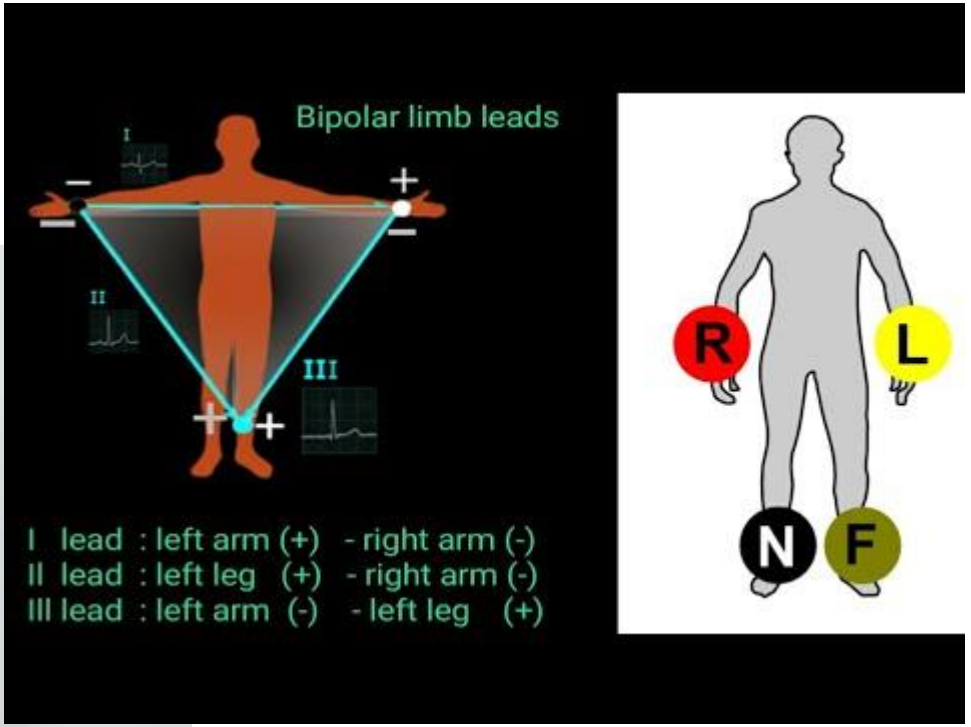
- obtained by connecting right arm and left leg.
- Right arm is connected to the negative terminal of the instrument and the left leg is connected to the positive terminal.

➢ Lead III

- obtained by connecting left arm and left leg.
- Left arm is connected to the negative terminal of the instrument and the left leg is connected to the positive terminal





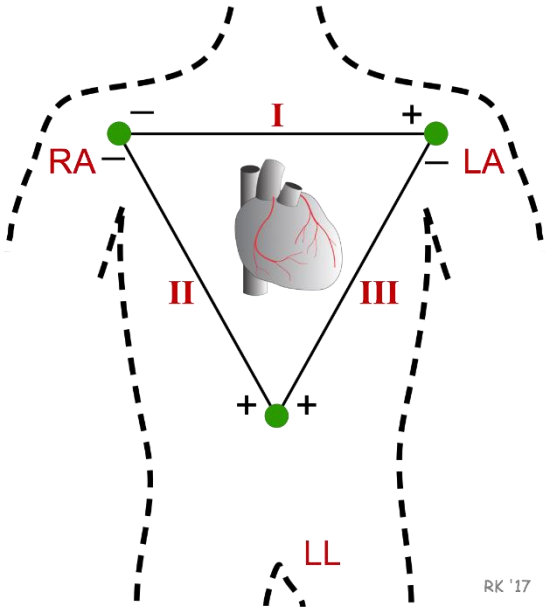

Bipolar limb leads
I
II
III
I lead : left arm (+) - right arm (-)
II lead : left leg (+) - right arm (-)
III lead : left arm (-) - left leg (+)
R
L
N
F

Einthoven triangle

- equilateral triangle that is used as a model of standard limb leads used to record electrocardiogram
- Heart is presumed to lie in the center of Einthoven triangle.
- Electrical potential generated from the heart appears simultaneously on the roots of the three limbs, namely the left arm, right arm and the left leg.

Einthoven law

- It states that if the electrical potential of any two of 3 bipolar limbs are known at any given instant, the 3rd can be calculated mathematically by summing the 1st two.
- I,e **Limb I + limb III = limb II**



UNIPOLAR LEADS

- one electrode is active electrode and the other one is an indifferent electrode (Active electrode is positive and the indifferent electrode is serving as a composite negative electrode)
- two types:

1. Unipolar limb leads
2. Unipolar chest leads

1. Unipolar Limb Leads

- also called augmented limb leads or augmented voltage leads
- Active electrode is connected to one of the limbs. Indifferent electrode is obtained by connecting the other two limbs through a resistance
- three types:

i**. aVR lead**

ii. aVL lead

iii. aVF lead

i. aVR lead

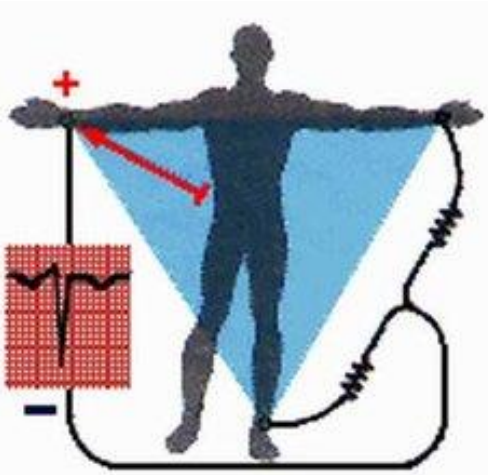
- Active electrode is from right arm.
- Indifferent electrode is obtained by connecting left arm and left leg.

ii. aVL lead

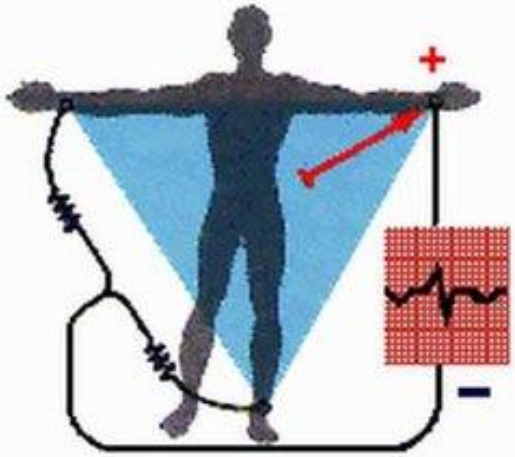
- Active electrode is from left arm.
- Indifferent electrode is obtained by connecting right arm and left leg.

iii. aVF lead

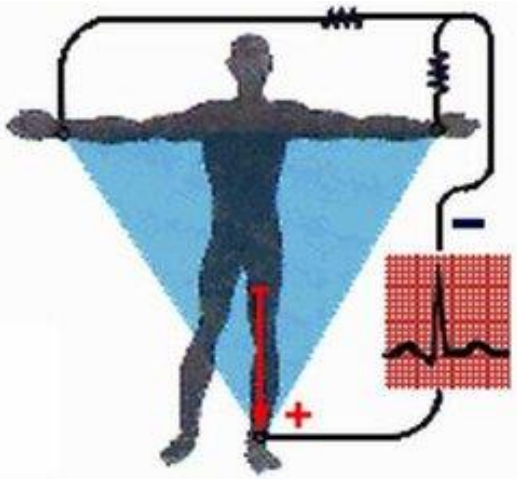
- Active electrode is from left leg (foot).
- Indifferent electrode is obtained by connecting the two upper limbs.



Lead aVR



Lead aVL



Lead aVF

2. Unipolar Chest Leads

- called ‘V’ leads or precardial chest leads. V indicates vector, which shows the direction of current flow.
- Indifferent electrode is obtained by connecting the three limbs, viz. left arm, left leg and right arm, through a resistance.
- Active electrode is placed on six points over the chest

- **Position of chest leads**

V1 : Over 4th intercostal space near right sternal margin

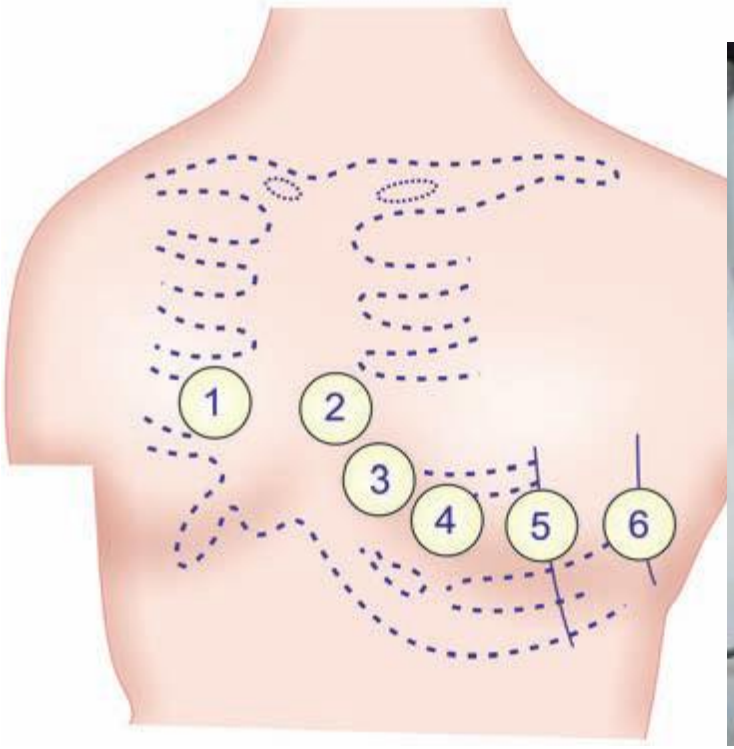
V2 : Over 4th intercostal space near left sternal margin

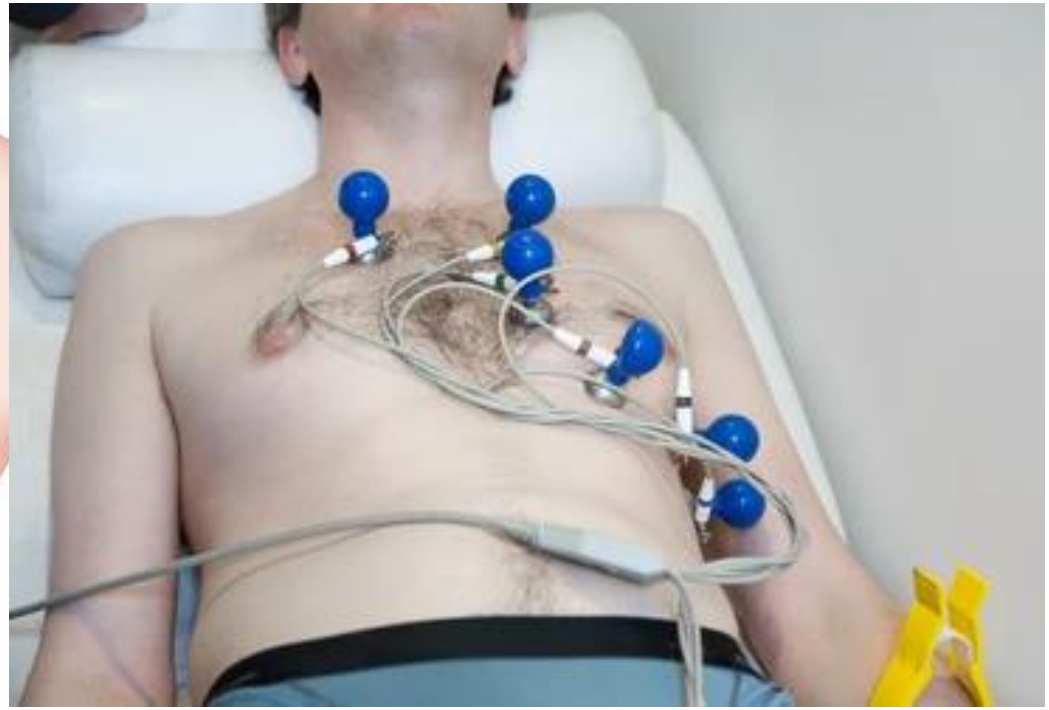
V3 : In between V2 and V4

V4 : Over left 5th intercostal space on the mid clavicular line

V5 : Over left 5th intercostal space on the anterior axillary line

V6 : Over left 5th intercostal space on the mid axillary line


1
2
3
4
5
6



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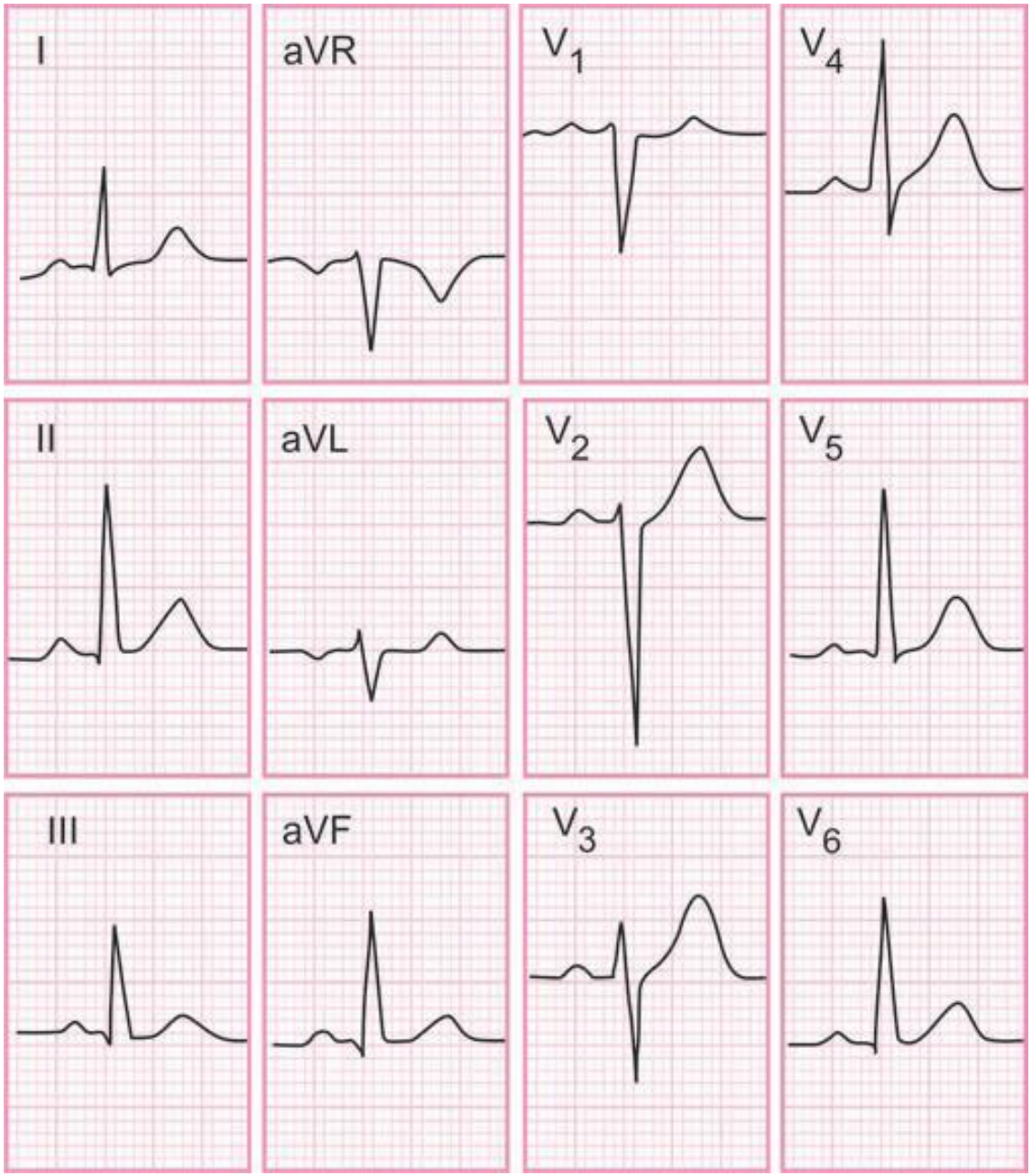

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

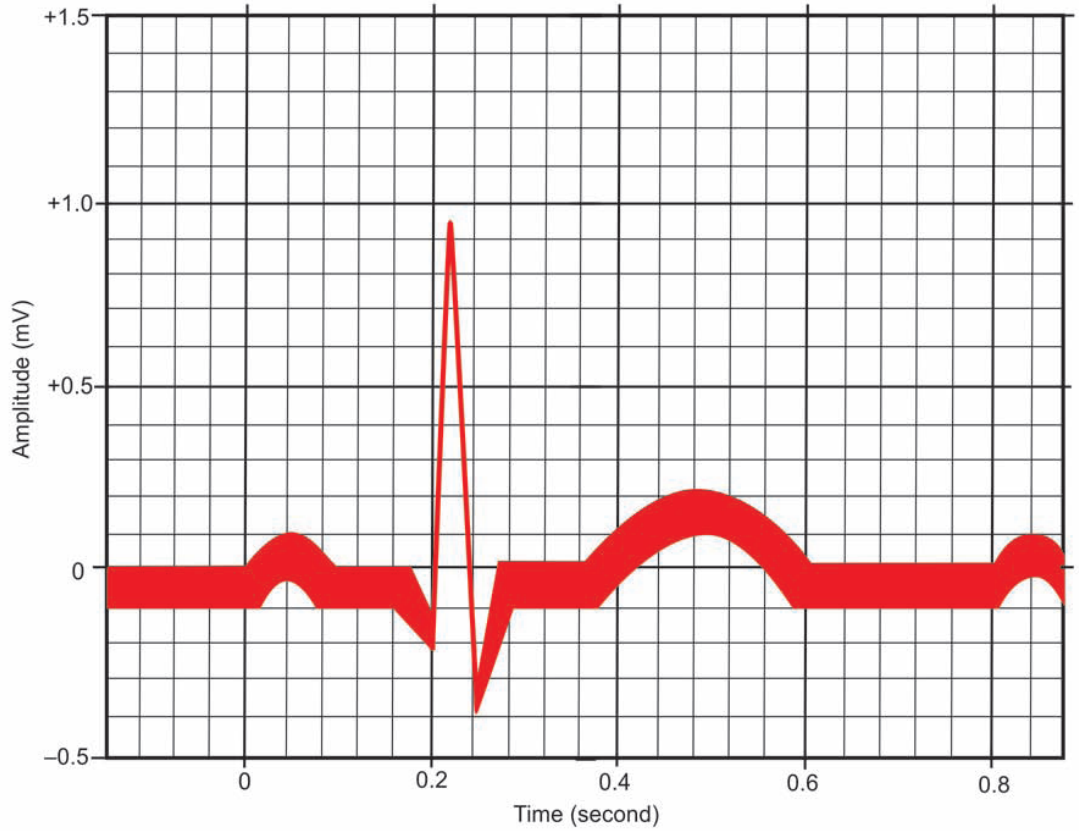
Contents of ECG

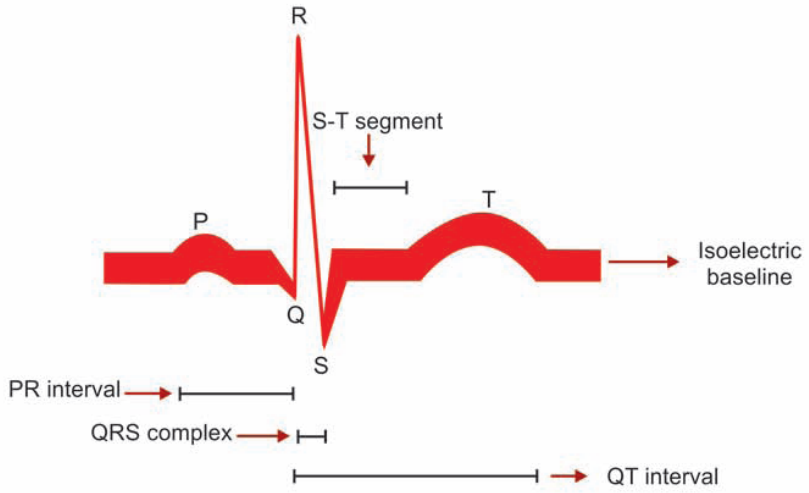
- ✓ waves
- ✓ complexes
- ✓ intervals
- ✓ segments

WAVES OF NORMAL ECG

- Normal electrocardiogram has the waves, namely P, Q, R, S and T

1. ‘P’ wave, the atrial complex
2. ‘QRS’ complex, the initial ventricular complex
3. ‘T’ wave, the final ventricular complex
4. ‘QRST’, the ventricular complex


+1.5
+1.0
+0.5
0
–0.5
Amplitude (mV)
0
0.2
0.4
0.6
0.8
Time (second)


R
S-T segment
T
P
Isoelectric baseline
Q
S
PR interval
QRS complex
QT interval

‘P’ WAVE

- ‘P’ wave is a positive wave
- first wave in ECG
- It is also called atrial complex.

➢ **Cause**

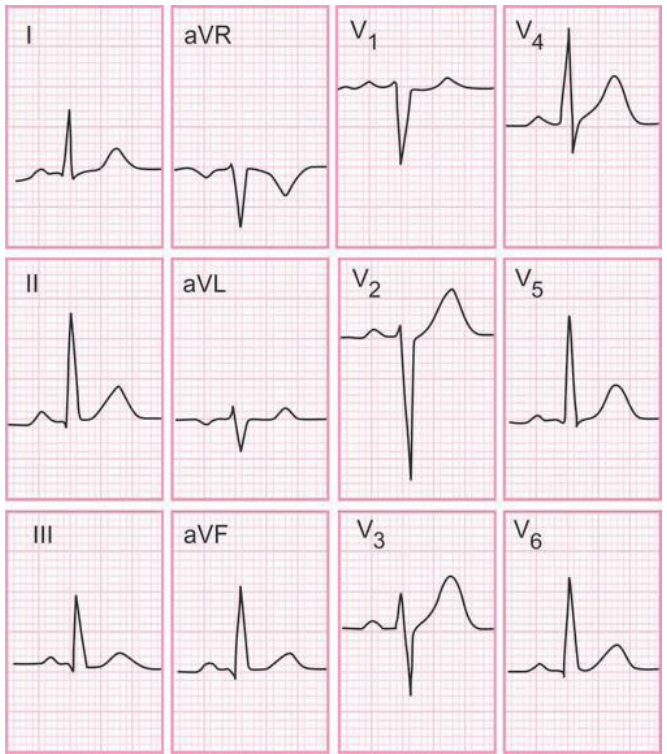
- produced due to the depolarization of atrial musculature

➢ **Duration**- 0.1 second

➢ **Amplitude-** 0.1 to 0.12 mV

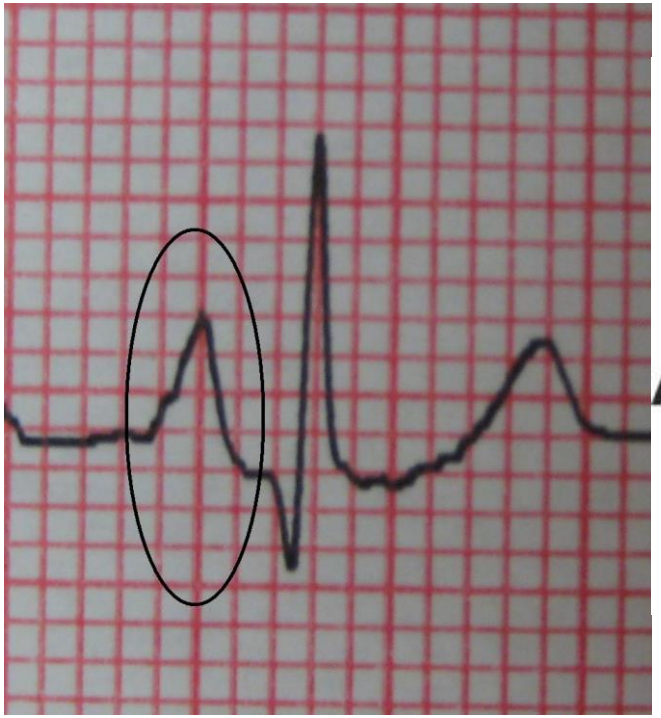
➢ Morphology

- ‘P’ wave is normally positive (upright) in leads I, II, aVF, V4 , V5 and V6 .
- It is normally negative (inverted) in aVR
- It is variable in the remaining leads



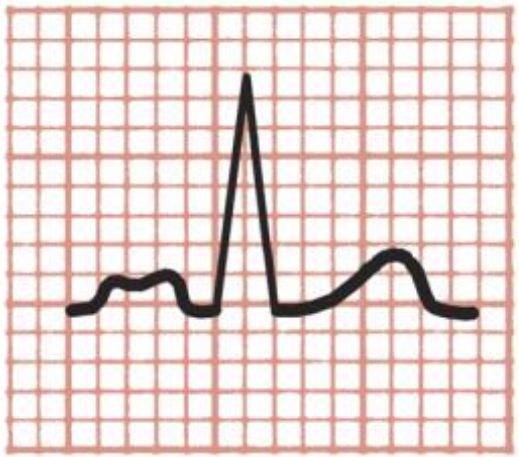
➢ Clinical Significance

1. **Right atrial hypertrophy**: ‘P’ wave is tall (more than 2.5 mm) . It is usually pointed
2. **Left atrial dilatation or hypertrophy**: It is tall and broad based or M shaped
3. **Hyperkalemia**: ‘P’ wave is absent or small
4. **Atrial fibrillation**: ‘P’ wave is absent

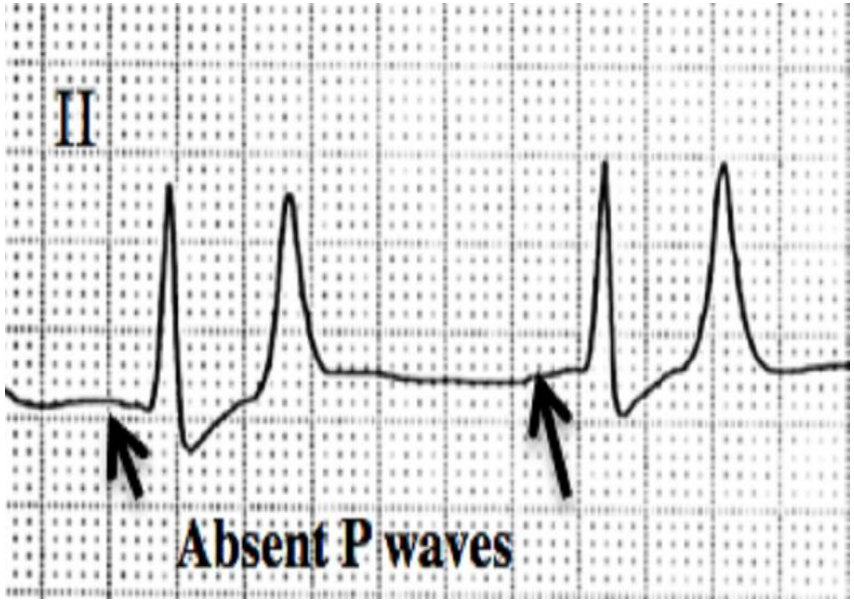


A

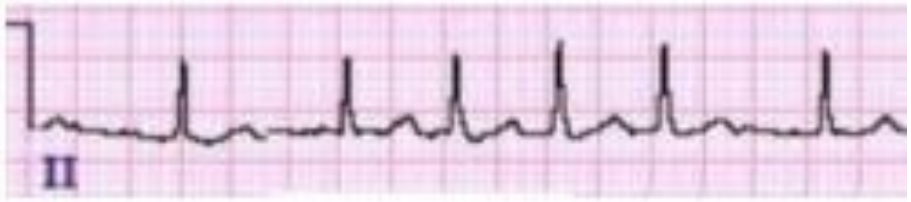
Left Atrial Abnormality



B



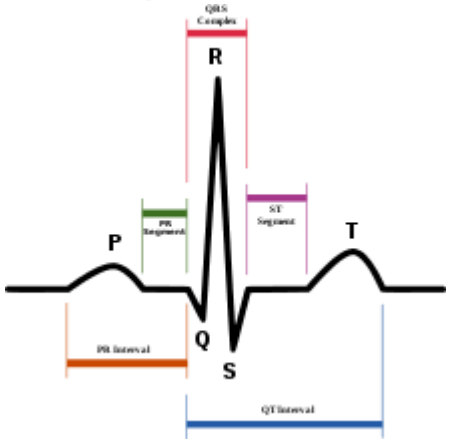
Atrial fibrillation



Atrial flutter

‘QRS’ COMPLEX

- also called the initial ventricular complex.
- ‘Q’ wave is a small negative wave.
- It is continued as the tall ‘R’ wave, which is a positive wave.
- ‘R’ wave is followed by a small negative wave, the ‘S’ wave



➢ Cause

- due to depolarization of ventricular musculature.
- ‘Q’ wave is due to the depolarization of mid portion of interventricular septum.
- ‘R’ wave is due to the depolarization of apical portion of interventricular septum and both the ventricles
- ‘S’ wave is due to the depolarization of basal portion of ventricles.

- **Duration**- 0.08 and 0.10 second
- **Amplitude-**

  Amplitude of ‘Q’ wave = 0.1 to 0.2 mV.

  Amplitude of ‘R’ wave = 1 mV.

  Amplitude of ‘S’ wave = 0.4 mV.
- **Morphology**

- ‘Q’ wave is less than 25% of amplitude of ‘R’ wave in leads I, II, aVL, V5 and V6
- In the remaining leads, its amplitude is < 0.2 mm.

➢ Clinical Significance

1. Bundle branch block: QRS is prolonged or deformed
2. Hyperkalemia: QRS is prolonged

‘T’ WAVE

- T’ wave is the final ventricular complex and is a positive wave

➢ **Cause**

‘T’ wave is due to the repolarization of ventricular musculature.

➢ **Duration-** 0.2 second

➢ **Amplitude-** 0.3 mV

➢ Morphology

- ‘T’ wave is normally positive in leads I, II and V5 and V6 .
- It is normally inverted in lead aVR.

➢ Clinical Significance

1. Old age, anxiety, myocardial infarction, left ventricular hypertrophy: ‘T’ wave is small, flat or inverted
2. Hypokalemia: ‘T’ wave is small, flat or inverted
3. Hyperkalemia: ‘T’ wave is tall

‘U’ WAVE

- ‘U’ wave is not always seen.
- It is supposed to be due to repolarization of papillary muscle/ purkinje fibers

Clinical Significance

1. Hypocalcaemia and hypokalemia: ‘U’ wave appears. It is very prominent in hypokalemia.
2. Myocardial ischemia: Inverted ‘U’ wave appears.

INTERVALS AND SEGMENTS OF ECG

- ‘P-R’ INTERVAL
- ‘Q-T’ INTERVAL
- ‘S-T’ SEGMENT
- ‘R-R’ INTERVAL

‘P-R’ INTERVAL

- interval between the onset of ‘P’ wave and onset of ‘Q’ wave/ R wave(if Q wave is absent)
- **Duration-** 0.18 sec
- It represents atrial depolarization plus conduction time of bundle of his.
- **Clinical Significance:**

1. It is prolonged in bradycardia and first degree heart block
2. It is shortened in tachycardia

‘Q-T’ INTERVAL

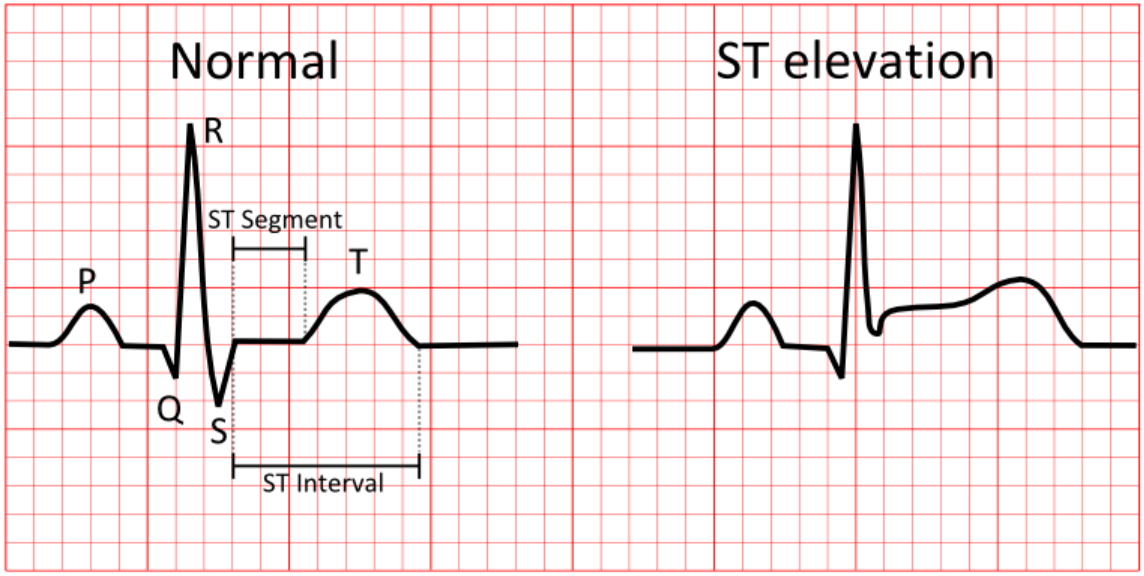
- interval between the onset of ‘Q’ wave and the end of ‘T’ wave
- indicates the ventricular depolarization and ventricular repolarization
- **Duration-** 0.4 and 0.42 sec
- **Clinical Significance**

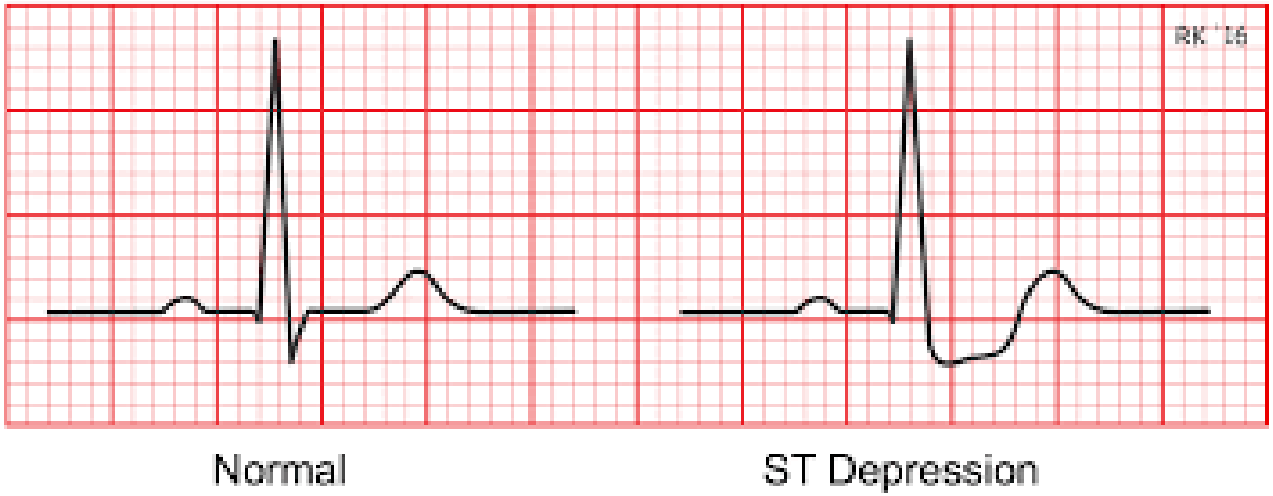
1. prolonged in hypocalcemia, myocardial infarction
2. shortened in hypercalcemia

‘S-T’ SEGMENT

- time interval between the end of ‘S’ wave and the onset of ‘T’ wave. It is an isoelectric period
- **J Point-** The point where ‘S-T’ segment starts is called ‘J’ point
- **Duration-** 0.08 sec
- **Clinical Significance-**

1. **Elevation of ‘S-T’ segment** occurs in anterior or inferior myocardial infarction
2. **Depression of ‘S-T’ segment** occurs in acute myocardial ischemia, hypokalemia
3. **‘S-T’ segment is prolonged** in hypocalcemia
4. **‘S-T’ segment** is shortened in hypercalcemia

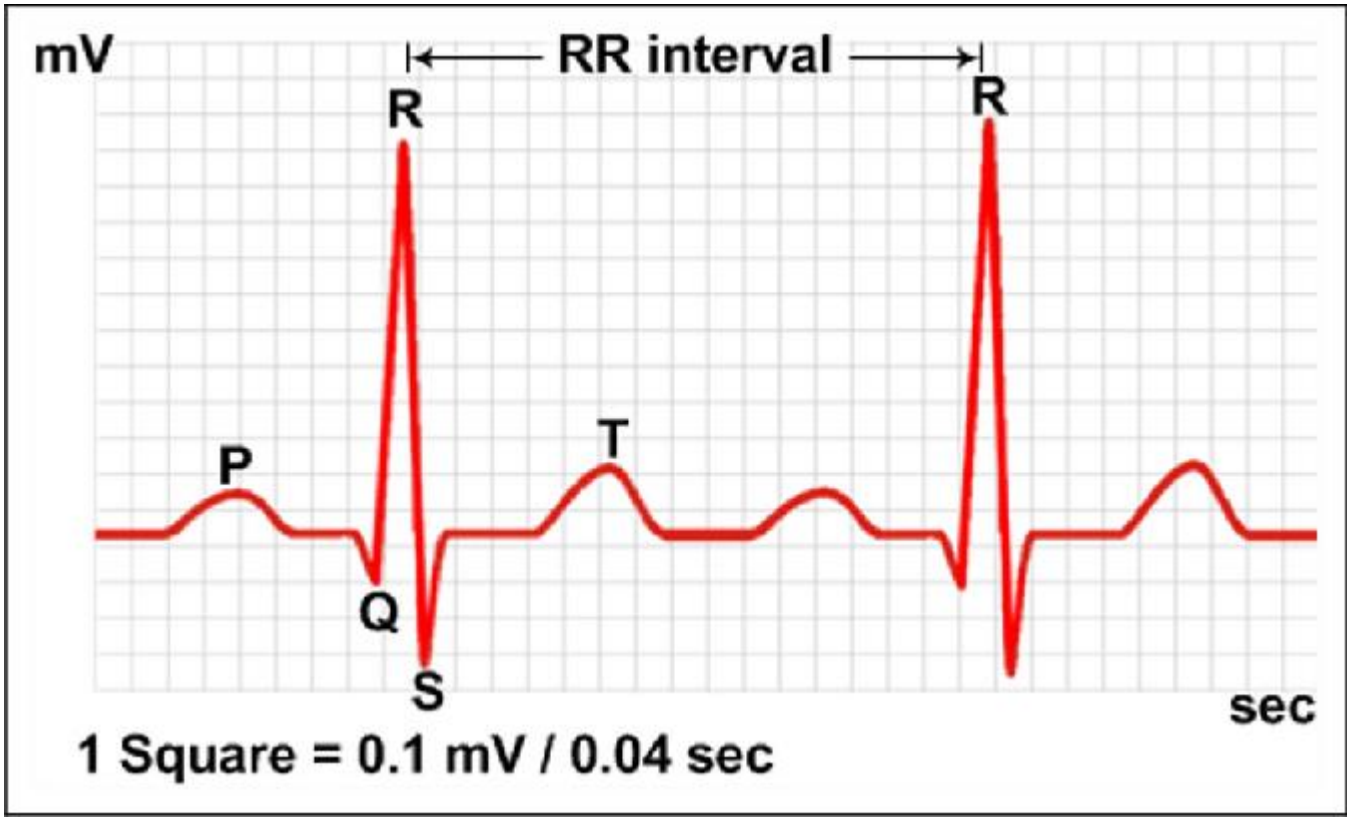

Normal
R
ST Segment
T
P
Q
S
ST Interval
ST elevation


RK '15
Normal
ST Depression

‘R-R’ INTERVAL

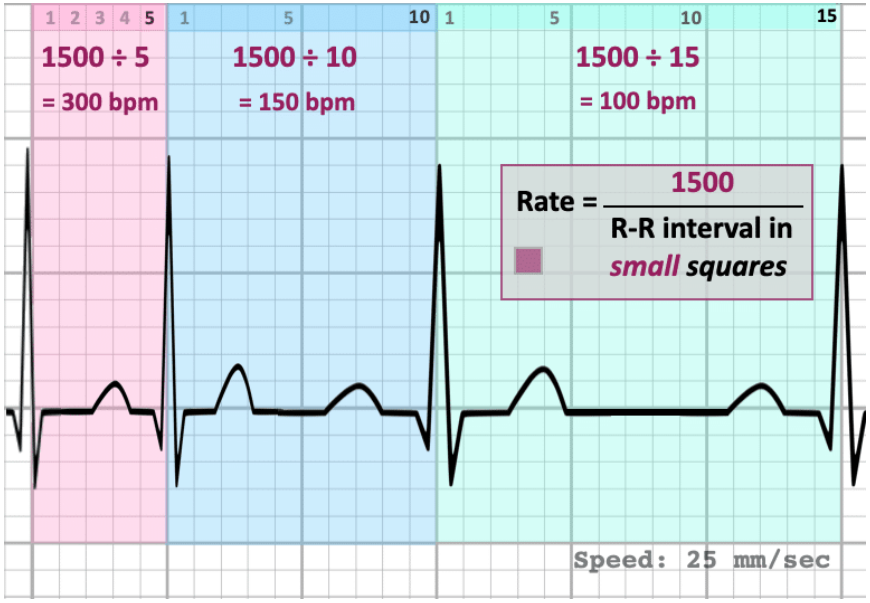
- time interval between two consecutive ‘R’ waves.
- Significance:

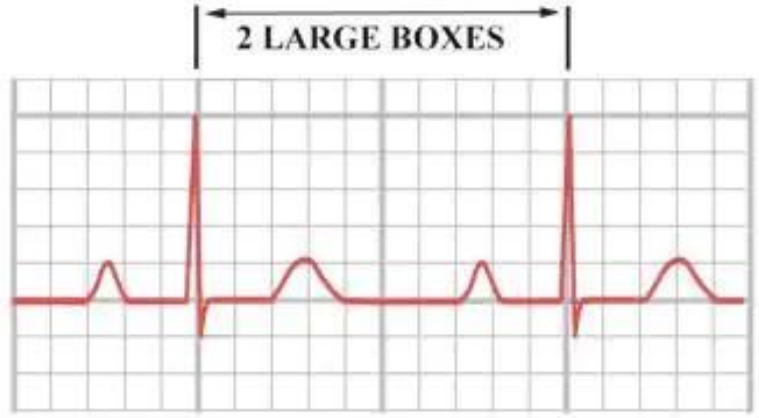
  Measurement of ‘R-R’ interval helps to calculate the Heart rate
- Duration- 0.8 sec


mV
RR interval
R
R
T
P
Q
S
sec
1 Square = 0.1 mV / 0.04 sec

Calculation of heart rate

- Interval between two thick lines is 0.2 sec
- Time duration for 30 thick lines is 6 seconds
- Number of ‘R’ waves (QRS complexes) in 6 seconds (30 thick lines) is counted and multiplied by 10 to obtain heart rate.





Heart Rate = 300 divided by 2 large boxes = 150 bpm

HR= 1500/ no. of small squares btw 2 successive R waves

HR = 300 / no. of large squares btw 2 successive R waves

Summary

Wave/Segment	From – To	Cause	Duration (second)	Amplitude (mV)
P wave	–	Atrial depolarization	0.1	0.1 to 0.12
QRS complex	Onset of Q wave to the end of S wave	Ventricular depolarization and atrial repolarization	0.08 to 0.10	Q = 0.1 to 0.2 R = I S = 0.4
T wave	–	Ventricular repolarization	0.2	0.3
P-R interval	Onset of P wave to onset of Q wave	Atrial depolarization and conduction through AV node	0.18 (0.12 to 0.2)	–
Q-T interval	Onset of Q wave and end of T wave	Ventricular depolarization and ventricular repolarization	0.4 to 0.42	–
S-T segment	End of S wave and onset of T wave	Isoelectric	0.08	–